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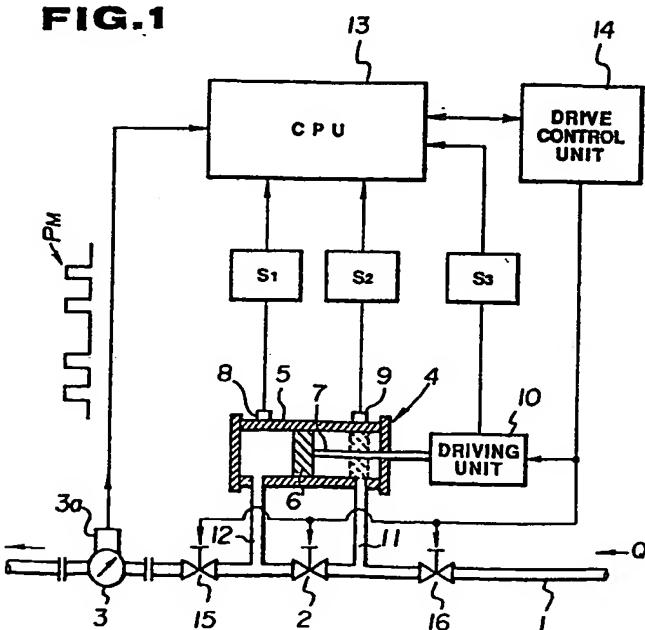
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## (54) Flowmeter proving apparatus

(57) A reliable meter factor can be obtained in a short time even when proving flowmeters having non-uniform pulse outputs per unit of volume flow using a small volume prover.

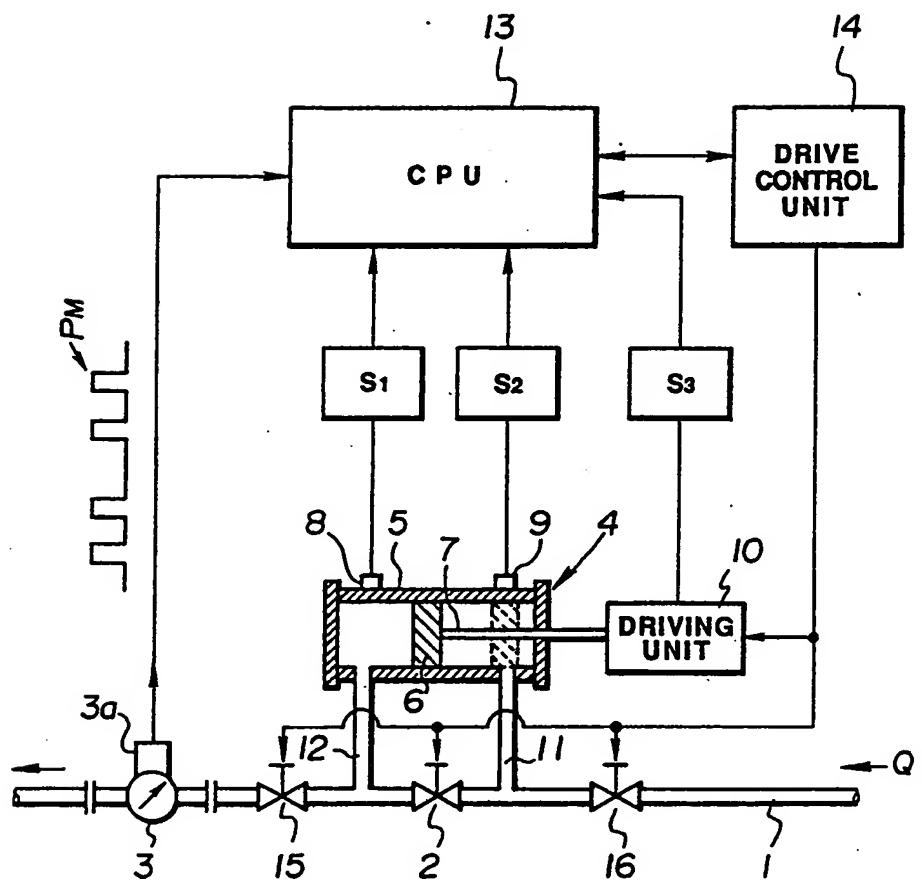
A line in which a flowmeter 3 to be proved and a small volume prover 4 are connected in series with each other also contains series valves 15, 16 and a prover by-pass valve 2, all controlled by CPU13. For proving, the valve 2 is closed and the other valves open. Piston 6 of the prover is moved through its travel, sending start and finish signals at positions 9 and 8 to the CPU, to count pulses emitted by generator 3a of the meter under test. A high frequency clock in the CPU allows a correction to be made for non-synchronisation between a start/stop signal and a meter pulse. Since the correction may be in error if there is any irregularity in the meter pulses with a constant flow, the CPU 13 calculates the irregularity of meter-pulse spacing with the prover 4 by-passed, and then determines the repeatability (%) for a proving run from the number of counted meter pulses and the meter pulse space irregularity. The CPU 13 then computes the proving pass number Np necessary for obtaining the required repeatability (%) by substituting the repeatability value into an another predetermined function, thus minimising the number of proving passes for the desired repeatability.



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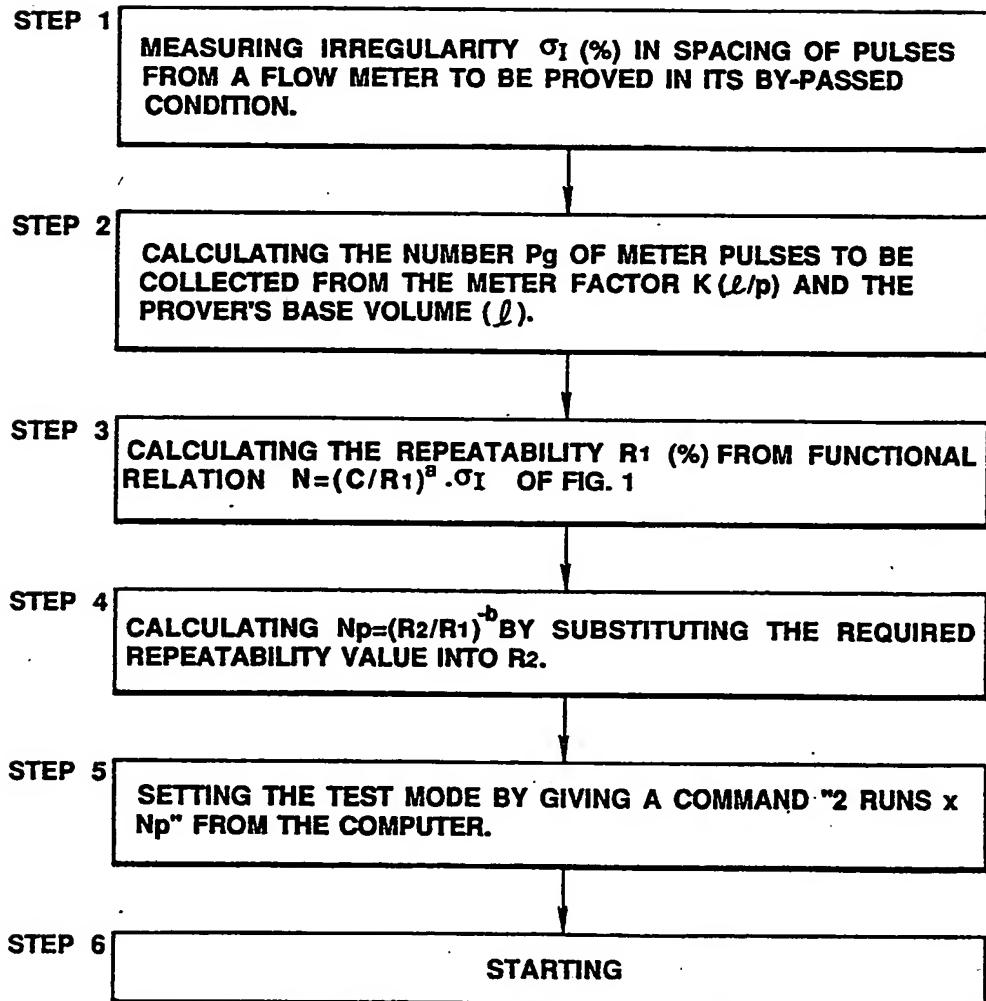
**FIG.1**



2/s

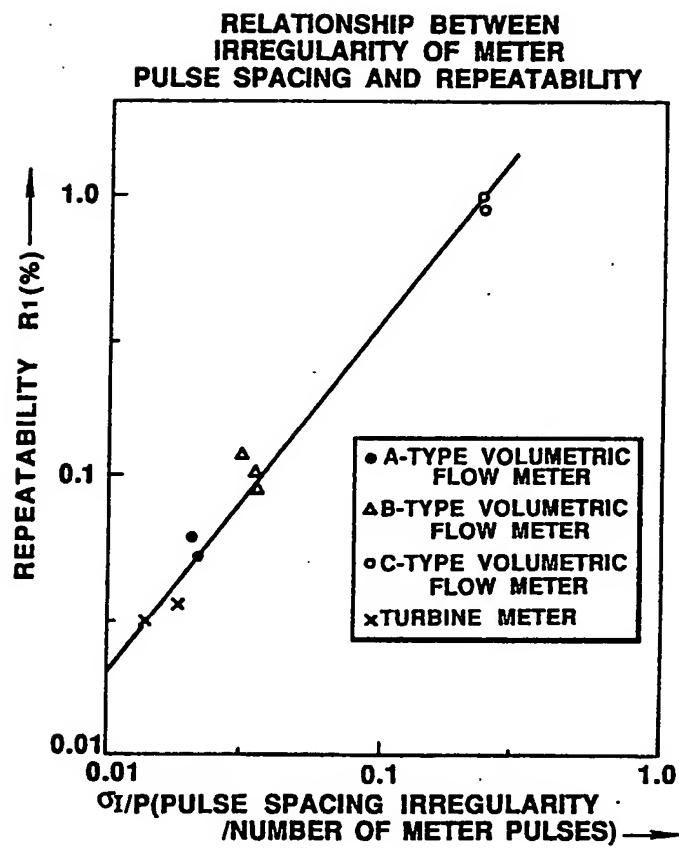
## FIG. 2

### FLOW CHART OF COMPUTER SOFTWARE



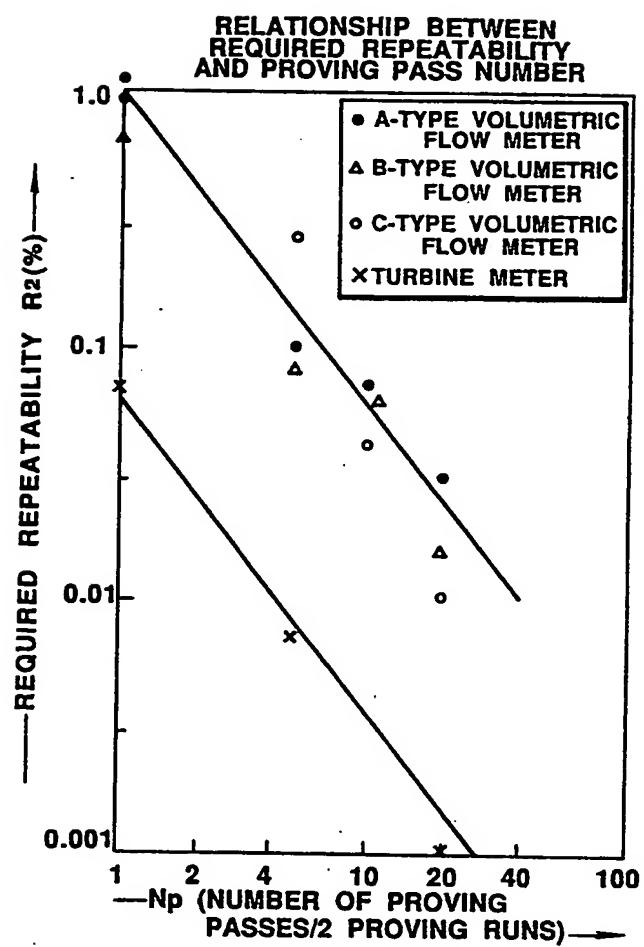
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**FIG. 3**



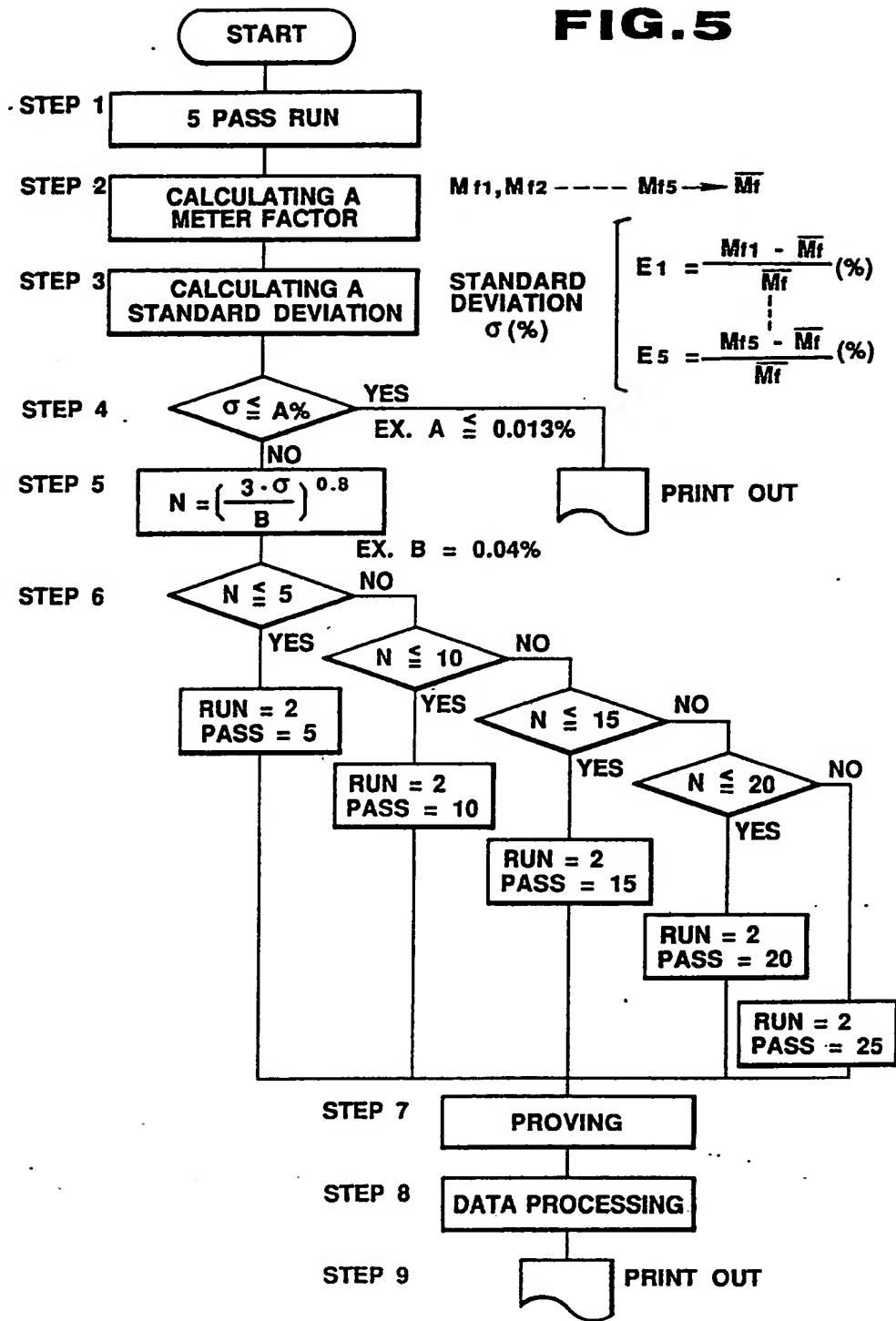
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**FIG. 4**



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**FIG.5**



## FLOWMETER PROVING APPARATUS

## BACKGROUND OF THE INVENTION

The present invention relates to a flowmeter proving apparatus for proving flowmeters having non-uniform pulse outputs by using a reference volume cylinder and more particularly to a flowmeter proving apparatus having the function of calculating the number of proving runs necessary for obtaining the required repeatability of the proving test by using a small volume prover.

There are two conventional methods for proving flowmeters, one of which is called "an absolute proving method" whereby a flowmeter to be proved is connected in series with a precision cylinder having a calibrated reference volume and its reading during the displacement of the fluid of the reference volume through the calibrated section of the cylinder is directly compared to the above-mentioned fluid's volume or weight, and the other is called "a comparison method" whereby the flowmeter's reading is compared with a standard flowmeter. The "absolute proving method" is applied in the case where a high accuracy of instrumental error-correction is required. Generally, the absolute proving method is classified into two methods; one is "the tank method" using a standard tank having the known volume of its portion defined by its upper and lower levels, and the other is "the pipe method" using a reference volume pipe having the known volume in its calibrated

section of the uniform cross-section.

The "standard tank method" cannot attain a high efficiency in performing proving tests since it requires much time and labor for reading the upper and lower levels, calculating the reference volume from the readings and so on. Conversely, in the case of "the pipe prover method", since whole meter pulses generated by a flowmeter to be proved are counted, and a rubber-made sphere of a diameter a little larger than the reference volume pipe's inside diameter is movable in the pipe under a low differential pressure of liquid therein, travels through the pipe section between its two positioned detectors (hereinafter called detectors). The result is compared with the reference volume and it is possible to obtain remote control and automated measurements thereby allowing the rationalization of the proving operation.

As regards the development of a flowmeter having a higher accuracy and a diversification of fluids for which flowmeters are used, it is necessary to achieve real time proving of the flowmeters through the pipe prover method using a small volume prover (hereinafter abbreviated to SVP) which is distinguished by its reduced size thereby allowing it to be transported by car or other vehicle by virtue of its short and small reference volume pipe.

The operating principle of SVP is such that a piston, sealably and slidably inserted in a cylinder of an even cross-section, travels through a calibrated section of the cylinder with its limits defined by the detectors to

displace a constant volume of fluid through a flowmeter to be proved by comparing its readings with the measured volume of the fluid.

SVP systems are disclosed in chapter 4 "Proving System" of The Manual of Petroleum Measurement Standards issued in June of 1988 by The American Petroleum Institute.

As mentioned above, the flowmeter proving method by using the SVP is meant to compare the fluid's volume in the calibrated section of the reference volume pipe defined by the signals emitted from the detectors with the number of meter pulses emitted from the flowmeter for the same period. A time-interval between the first detector signal at proving pass start and the first meter pulse following said detector signal and the time-interval between the last detector signal at the proving pass end and the meter pulse proceeding or following said detector signal, i.e. volume less than meter pulse spacing, are determined as ratios to the number of high frequency clock pulses and a fractional part of the displaced volume are calculated as a sum of or the difference between the ratios (by the double-timing method).

However, the double-timing method requires the conducting of the proving at a constant flow-rate and the generation of meter pulses at a uniform pulse spacing, that is, if the flow-rate varies or the pulses are emitted in non-uniform pulse spacing, the result may involve a corresponding error.

The flowmeter's pulse space dispersion depend upon the

types of flowmeters to be proved. For example, a turbine meter, in which a rotor, rotatable in proportion to the flow-rate to be measured, is placed close to the flowmeter sensor, may generate equally spaced pulses of an excellent SN-ratio while pulse dispersion may occur in the case of a flowmeter having a rotary transmitting mechanism such as a gear train between a rotor and a meter pulse generator as well as a positive displacement flowmeter wherein a rotor's rotation angle is not proportional to the flowmeter's displacement.

The above-mentioned manual of API proposes that in case of a flowmeter having a rotor placed adjacent to the meter pulse generator, the proving test shall be conducted five times (by five proving passes) in order to attain a meter repeatability of 0.05% and a meter factor (in liters per pulse) shall be calculated as an average of values obtained by these five tests.

In a proving test of a flowmeter, generating irregularly spaced pulses representing certain flow-rates, it is necessary to increase the number of a piston's travels (hereinafter called the number of proving passes) or to set larger allowances for repeatability.

For instance, in order to obtain a repeatability of not more than 0.1% it is necessary to conduct 10 proving passes. Furthermore, increasing the number of proving passes increases the flowmeter's repeatability and also improves the quality of the mean's value.

However, there is no description of the relationship

between a number of proving passes, the required repeatability and the meter pulse variations.

#### SUMMARY OF THE INVENTION

It is an object of the present invention was made in order to provide a flowmeter prover which is capable of determining a number of proving passes necessary for getting the required repeatability in a proving test of a flowmeter generating irregularly spaced pulses.

It is another object of the present invention to provide a flowmeter prover which capable of the obtaining of a reliable meter factor and reducing the proving test time by reducing unnecessary proving passes.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an example of a principal configuration of a flowmeter proving apparatus embodied in the present invention.

Fig. 2 shows a flow-chart for computer software.

Fig. 3 is showing an example of the proving result concerning the relationship between the irregularity of meter pulse spacing and repeatability.

Fig. 4 is showing an example of a proving result showing the relationship between required repeatability (%) and a number of proving passes.

Fig. 5 shows the flow-chart of a central processing

unit of another flowmeter proving apparatus according to the present invention.

#### Description of the preferred embodiment

In order to achieve the above-mentioned object the present invention provides a flowmeter prover (1) for use in a system for proving a flowmeter irregularly generating a series of pulses with a constant flow factor at a constant flow rate and connected in series with a reference volume cylinder of a constant cross-section including a piston capable of sealably sliding therein to displace a reference volume of fluid through a calibrated section of the cylinder for the purpose of determining a meter's factor by comparing the number of pulses from the flowmeter to be proved with the displaced reference volume; and which further comprises a central processing unit (CPU) including, a means for measuring the irregularities of the spacing of meter pulses generated by the flowmeter to be proved, a means for calculating the number of meter pulses from the reference volume and the meter factor, a means for calculating the repeatability of a proving run according to the relationship between the repeatability of a proving run and the irregularity of the pulse spacing for a predetermined number of meter pulses, a means for calculating the required repeatability of the flowmeter to be proved according to the relationship between the required repeatability and the number of proving passes for a number of proving runs

necessary for obtaining said repeatability; and a drive control unit for driving the reference volume cylinder piston according to the output of the central processing unit; or a flowmeter prover (2) for use in a system for proving a flowmeter irregularly generating a series of pulses with a constant flow factor at a constant flow rate and connected in series with a reference volume cylinder of a constant cross-section including a piston being capable of sealably sliding therein to displace a standard volume of fluid through a calibrated section of the cylinder for the purpose of determining a meter factor by comparing the number of pulses from the flowmeter to be proved with the displaced reference volume; and which further comprises a central processing unit including a means for predetermining a number of proving passes for a proving run and calculating a meter factor for the number of proving passes, a means for calculating a standard deviation of the calculated meter factors, a means for judging a finishing of a proving test when the standard deviation is not more than a given repeatability of the meter factor, determining a proving pass number for a proving run according to the standard deviation value of the meter factor when the standard deviation exceeding the given repeatability and conducting two proving runs when the proving pass number exceeding the given number; and a drive control unit for driving the reference volume cylinder according to the output of the central processing unit.

A preferred embodiment of the present invention will be

described as follows:

Fig. 1 is a block diagram showing the principal construction of a flowmeter proving apparatus according to the present invention, which is composed of a fluid-flowing pipe 1, a by-pass valve 2, a flowmeter 3 to be proved, a flow-rate pulse generator 3a, a small volume prover 4, a piston 6, a cylinder 5, a piston rod 7, detectors 8 and 9, a driving unit 10, conduits 11 and 12, a central processing unit (CPU) 13, a drive control unit 14 and valves 15 and 16.

In the case of the flowmeter proving apparatus shown in Fig. 1 the cylinder 5 serves as a reference volume pipe with both closed ends, which is precisely finished to be of a uniform inside diameter and provided with an internally sealing means (not shown) to allow the piston 6 to travel therein with no leakage. The piston 6 has at one end the piston rod 7 which is connected to the opposite end to the driving unit 10 for driving the piston 6 to move in its axial direction. The driving unit 10 also includes a position sensor (not shown) which detects the travels of the piston 6 and emits a position signal  $S_3$  per unit of micro-distance when necessary. The detectors 8 and 9 are placed on the outside wall of both ends, respectively, of the cylinder 5. These detectors 8 and 9 emit position signals  $S_1$  and  $S_2$  respectively when the piston 6 passes through the positions detected by them. The reciprocating movement of the piston 6 in the cylinder 5 is realized by operating the valves 2, 15 and 16 according to command signals generated from the CPU 13.

The operations of the flowmeter proving apparatus are as follows:

A proving test starts when the CPU emits a starting signal on condition that the piston 6 is in the starting position indicated by a dotted line. The drive control unit 14 places the valves 15 and 16, in an open position and the valve 2 in a closed position while the driving unit 10 causes the piston to move at a constant speed. If the fluid's flow fluctuates, the moving speed of the piston 6 is controlled according to the position signal  $S_3$  so as to maintain a constant flow-rate.

When the piston 6 passes through the detector 9, a detecting signal  $S_2$  is emitted and the meter pulse generator 3a of the flowmeter to be proved generates a series of pulses  $P_M$  with non-uniform pulse spacings, which are counted until the piston 6 reaches the position of the detector 8. In the meantime the CPU 13 generates clock pulses of a high frequency (e.g. 100 kHz), by which means a volume less than a meter of pulse is detected by detecting both meter pulses succeeding respectively to detector signals  $S_1$  and  $S_2$  and so one proving pass is completed.

When a proving pass is finished, the valve 15 is closed, the by-pass valve 2 and the valve 16 are opened to return the piston 6 to the initial position indicated by a dotted line. Since the piston's positions when the meter pulses  $P_M$  are emitted, succeeding respectively to detector signals  $S_1$  and  $S_2$  may be uncertain and unequal, the obtained proving result may include an unexpected error.

In the case when the proving pass is repeated several times, there occurs a dispersion between the proving pass results which corresponds to the extent of the non-uniformity. For this reason, the number of proving passes is increased to improve the certainty of the test results. To improve the repeatability expressed in a percent, a proving run consisting of multiple proving passes is carried out and the repeatability of the test results is calculated as the repeatability of a proving run. The proving run is repeated, i.e. two proving runs are conducted.

Fig. 3 is showing an example of a proving result expressing the relationship between the meter pulse spacing irregularities and the repeatabilities of the positive displacement flowmeters A, B, C differing from each other by their design and a turbine meter. Each positive displacement flowmeter is provided with a transmission gear train. The graph, where the standard deviation  $\sigma_I$  (%) of the irregularity of the meter pulse spacing in relation to the number of counted meter pulses is represented by the horizontal axis and the repeatability  $R_1$  (%) of a proving run is represented by a vertical axis, gives the following relationship:

As is apparent from the relationship, the repeatability  $R_1$  for a proving run can be improved by reducing the irregularity  $\sigma_1$  of the meter pulse spacing. A constant  $C$  and the exponent  $a$  (e.g.  $a=1.0$ ,  $C=4$ ) are determined by

### functional relationships.

Fig. 4 is showing an example of proving results concerning the correlation between the required repeatability (%) and the number of proving passes for the same flowmeters as those proved in the tests of Fig. 2. The horizontal axis (abscissa) represents the proving pass number  $N_p$  required for two proving runs and the vertical axis (ordinate) represents the required repeatability  $R_2$  (%). From the graph the required number of proving passes for two proving runs is obtained as follows:

$$Np = (R_2/R_1)^{-b} \dots \dots \dots (2)$$

This relational expression shows that by increasing the required number of proving pulses  $N_p$  reduces the repeatability value and improves the reproducibility. An exponent  $b$  (e.g.  $b=0.8$ ) is determined by a functional relationship.

The present invention allows CPU 13 to determine the number of proving passes necessary for obtaining the required repeatability (%) based on the data indicated in Fig's. 2 and 3: calculates the proving pass number  $N_p$  required for two proving runs and then gives a command to the drive control unit 14 to repeat the test by the required number of passes.

Fig. 2 shows a flow chart of computer software composed of the following steps:

Step 1: The irregularity  $\sigma_I$  (%) in the spacing of meter pulses generated by the flowmeter to be proved is measured by the conditions of the by-pass valve 2

being open and the piston 6 being still. In this case, meter pulses are sampled consecutively by  $N$  pulses and a standard deviation of the irregularity  $\sigma_I$  from an average value  $X$ .

Step 2: The number  $P_g$  of meter pulses to be collected is calculated from the meter pulses, meter factor  $K$  (1/p:liter/pulse) and the prover's reference volume (1:liter).

Step 3: The repeatability  $R_1$  (%) for a proving run is calculated from the functional relationship (1)  $N = (C/R_1)^a \cdot \sigma_I$  according to Fig. 2 showing the relationship between the repeatability and the meter pulse spacing's irregularity.

Step 4: The number  $N_p$  of the proving pulses required for two proving runs, according to the functional relationship (2)  $N_p = (R_2/R_1)^{-b}$ , is derived from the correlation between the repeatability and proving pass number  $N_p$  shown in Fig. 3.

Step 5: The test mode is set in the CPU 13 by giving the command "Np x 2 runs".

Step 6: A command for conducting the flowmeter proving test according to the preset test mode is given to the drive control unit 14.

In the above-mentioned arithmetical operations, the first step determines the pulse spacing irregularity  $\sigma_I$  (%) of the flowmeter to be proved as a standard deviation value  $\sigma_I$  and the second step determines the number of pulses to be accumulated in proportion to a magnitude of standard

deviation  $\sigma_I$ . The number  $N$  of meter pulses to be counted is determined as a value relating to the repeatability  $R_1$  for one proving run. However, since the meter pulse number  $N$  in practice may be fixed depending on the flowmeter to be proven and the small volume prover, there is no need of specially calculating the above-mentioned pulse number  $N$ .

Fig. 5 shows a flow chart of a CPU for another flowmeter proving apparatus embodying the present invention. For example, the number  $N_p$  of proving passes during a proving run, i.e. the number of piston movements for one proving run is previously set. The meter factor for each proving pass number is calculated and a standard deviation  $\sigma$  of the calculated meter factors is then determined. The number of proving passes for a proving run, necessary for obtaining the repeatability determined in accordance with the standard deviation value  $\sigma$ , can now be determined.

Step 1: The proving pass number  $N_p$  for a proving run is determined to be five at a steady flow-rate.

Step 2: The average value  $M_f$  of five meter factors  $M_{f1}$ ,  $M_{f2}$ ,  $M_{f3}$ ,  $M_{f4}$  and  $M_{f5}$  measured at step 1 for every five proving passes is calculated.

Step 3: An error dispersion  $i$  ( $i=1, 2, \dots, 5$ ) is calculated from the meter factors  $M_{f1}$ ,  $M_{f2}$ , ...,  $M_{f5}$  for every proving pass and the average value  $M_f$  of the meter factors and then a standard deviation  $\sigma$  is computed from the positive square root of the error dispersion.

Step 4: When the calculated standard deviation  $\sigma$  is less or

equal to the limited accuracy, for example, of 0.013% of the small volume prover, the proving test is ended with the printing out of the standard deviation value  $\sigma$  as the repeatability of the flowmeter.

Step 5: If the calculated standard deviation  $\sigma$  is more than the limited accuracy of 0.013% of the small volume prover, another repeatability, for example,  $B=0.04\%$  to be obtained and the standard deviation value  $\sigma$  are substituted into the following equation:

$$N_p = (3\sigma/B)^\alpha \quad (\alpha: \text{constant}) \dots \dots \dots \quad (3)$$

in order to determine the number  $N_p$  of proving passes when the flowmeter test is to be conducted by two proving runs. The present applicant has obtained the experimental value  $\alpha=0.8$  according to the equation (3).

Step 6: By substituting the standard deviation value  $\sigma$  obtained at step 3 and value  $B=0.04\%$  into the equation (3) the numbers  $N_p$  of the proving passes are calculated as multiples of the integer  $N=5$ , i.e.  $N \leq 5$ ,  $N \leq 10$ ,  $N \leq 15$ ,  $N \leq 20$  which increase as the standard deviation values  $\sigma$  increase, and then the corresponding value  $N$  is adopted as a setting value.

Step 7: Based on the proving pass number  $N$ , e.g. of  $N > 5$ , determined at step 6, the flowmeter proving test is conducted in two runs with 5 proving passes each.

Step 8: By processing the test result data obtained at step 7 a meter factor for each of the two proving run's

is calculated and then a meter factor for two proving runs is finally determined as an average of the two meter factor values.

Step 9: The calculation results are printed out.

As is apparent from the foregoing description, according to the present invention, it is possible to provide the following effects:

Effect corresponding to Claim 1: In the case of proving a flowmeter, having a non-uniform pulse output by the use of a small volume prover, the present invention provides the possibility to automatically set the number of proofs necessary for obtaining the required repeatability (whereas the conventional method requires an increasing number of proving runs to improve the repeatability), a reliable meter factor may be obtained and furthermore the unnecessary number of tests may be reduced thus saving time.

Effect corresponding to Claim 2: Since the number of proving passes necessary for attaining the required repeatability can be determined according to the experimental value based on the standard deviation of the meter factor calculated by adopting the preset number of proving passes for a proving run at the given flow-rate, the flowmeter proving can be rationalized.

## CLAIMS

(1) A flowmeter proving apparatus for proving a flowmeter irregularly generating pulsed outputs with a given meter factor at a constant flow-rate, comprising:  
a reference volume cylinder with a uniform cross-section which is connected in series with the flowmeter to be proved and which has a piston capable of sealably sliding therein to displace a reference volume of fluid through a calibrated section thereof for the purpose of determining the meter factor by comparing the number of pulses generated by the flowmeter to the reference volume; a central processing unit including a means for measuring irregularities in the spacing of meter pulses generated by the flowmeter to be proved, a means for calculating the number of meter pulses from the reference volume and the meter factor, a means for calculating the repeatability of a proving run according to the relationship between the repeatability of a proving run and the irregularity of the pulse spacing for a predetermined number of meter pulses, a means for calculating the required repeatability of the flowmeter to be proved according to the relationship between the required repeatability and the number of proving passes for a number of proving runs necessary for obtaining said repeatability; and a drive control unit for driving the reference volume cylinder piston according to the output of the central processing unit.

(2) A flowmeter proving apparatus for proving a flowmeter

irregularly generating pulsed outputs with a given meter factor at a constant flow-rate, comprising; a reference volume cylinder with a uniform cross-section which is connected in series with the flowmeter to be proved and which has a piston capable of sealably sliding therein to displace a reference volume of fluid through a calibrated section thereof for the purpose of determining the meter factor by comparing the number of pulses generated by the flowmeter to the reference volume; a central processing unit including a means for predetermining a number of proving passes of a proving run and for calculating a meter factor for the number of proving passes, a means for calculating the standard deviation of the calculated meter factors; and a means for judging a finishing of a proving test when the standard deviation is not more than the given repeatability of the meter factor, determining a proving pass number for a proving run according to the standard deviation value of the meter factor when the standard deviation exceeds the given repeatability, and for conducting two proving runs when the proving pass number exceeds the given number; and a drive control unit for driving the base volume cylinder according to the output of the central processing unit.

(3) A flowmeter proving apparatus for proving a flow meter generating irregular pulse outputs when metering fluid at a constant flow rate, comprising supplying means operable for supplying at a constant flow rate to the flowmeter to be proved a known reference volume for the purpose of determining the meter factor of the meter by comparing the number of pulses generated by the flowmeter to the reference volume characterized in that said apparatus includes means for determining the number of times said supplying means is required to be operated to obtain a value for the meter factor which provides a desired repeatability of the flowmeter.

(4) An apparatus as claimed in claim 3, wherein said determining means includes means for calculating the standard deviation of the time spacing of the pulses or of successively determined meter factors.

(5) A flowmeter proving apparatus constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in the accompanying Figures.

Patents Act 1977

Examiner's report to the Comptroller under  
Section 17 (The Search Report)

Application number

9125746.9

Relevant Technical fields

(i) UK CI (Edition )  
K G1N (NAHA)

Search Examiner

(ii) Int CI (Edition 5 ) G01F 25/00

M G CLARKE

Databases (see over)

(i) UK Patent Office

Date of Search

(ii)

20 FEBRUARY 1992

Documents considered relevant following a search in respect of claims

1 TO 5

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A, &	US 4631951 (ass. to Bopp & Reuther GmbH) - Whole document (equivalent EP 0172465 in German)	1-3

SF2(p)

kg - c:\wp51\doc99\fil000719

Category	Identity of document and relevant passages	Relevant to claim(s)

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